Project Report

Suwannee River water Management Area 3 LiDAR Florida State Plane North

Prepared For:

United States Geological Survey

Prepared By:

Digital Aerial Solutions, LLC

CONTRACT: #G10PC00093
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TASK ORDER: #G12PD00242

Project Report
LiDAR Collection, Processing, and QA/QC

2012 Suwannee Management LiDAR Task Order

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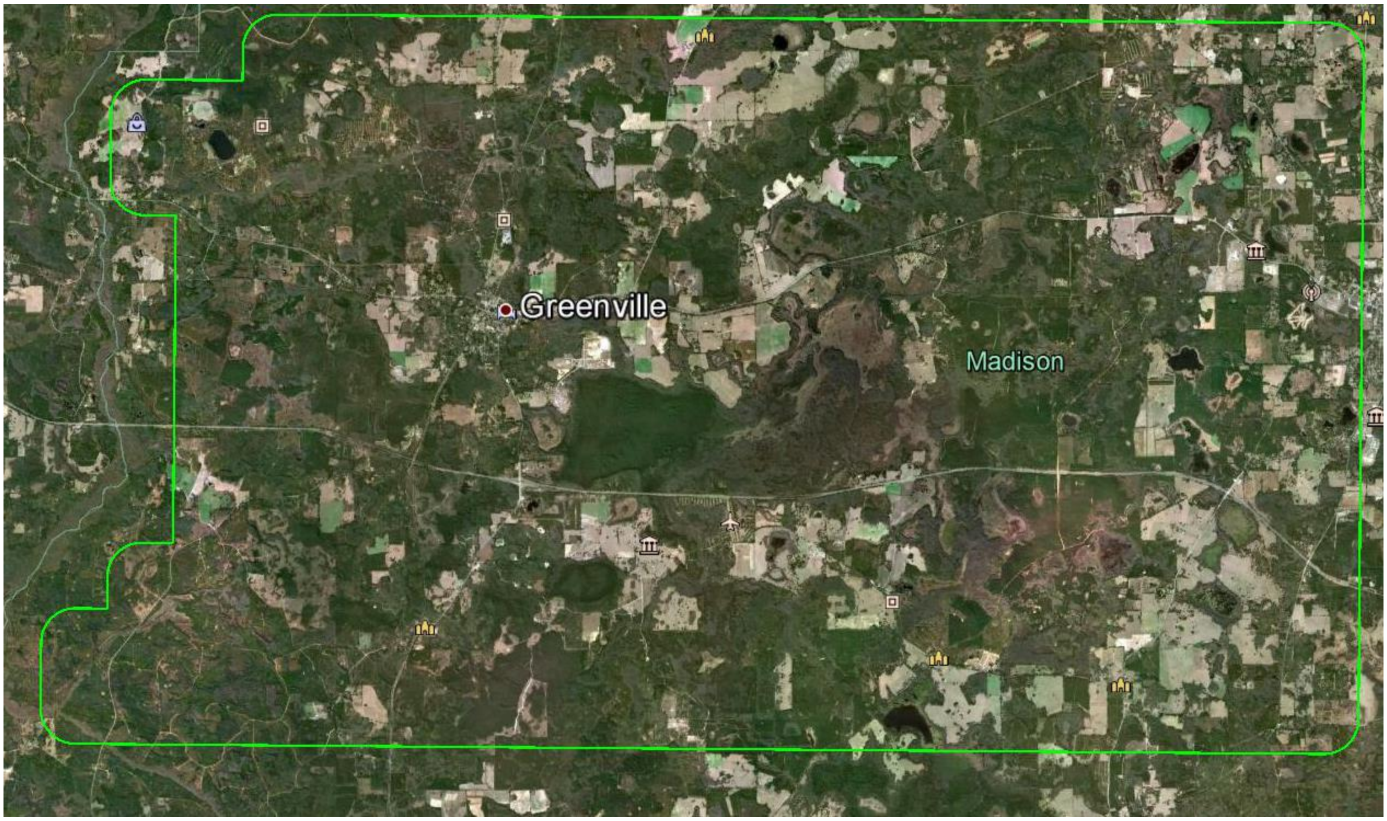
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1 Introduction and Specifications

Digital Aerial Solutions, LLC (DAS) was tasked to collect and process a Light Detection And Ranging (LiDAR) derived elevation dataset for the Suwannee Management, FL. The Suwannee Management survey area encompasses approximately 184 square miles. Aerial LiDAR data was collected utilizing an ALS60. The ALS60 is a discrete return topographic LiDAR mapping system manufactured by Leica Geosystems. LiDAR data collected for the Suwannee Management survey has a nominal pulse spacing of 0.9 meters, and includes up to 4 discrete returns per pulse, along with intensity values for each return.

LiDAR datasets were post processed to generate elevation point cloud swaths for each flight line. Deliverables include the point cloud swaths, tiled point clouds classified by land cover type, breaklines to support hydro-flattening of digital elevation models (DEM)s, and bare-earth DEM tiles. Point cloud deliverables are stored in the LAS version 1.2 format, point data record format 1. The tiling scheme for tiled deliverables is a 4900 feet x 4900 feet grid. All deliverables were generated in conformance with the *U.S. Geological Survey National Geospatial Program Guidelines and Base Specifications, Version 1.*

2 Spatial Reference System

The spatial reference of the data is as follows.

Horizontal Spatial Reference

- Datum: North American Datum of 1983 (National Spatial Reference System 2007)
- Coordinates: Florida State Plane North

Vertical Spatial Reference

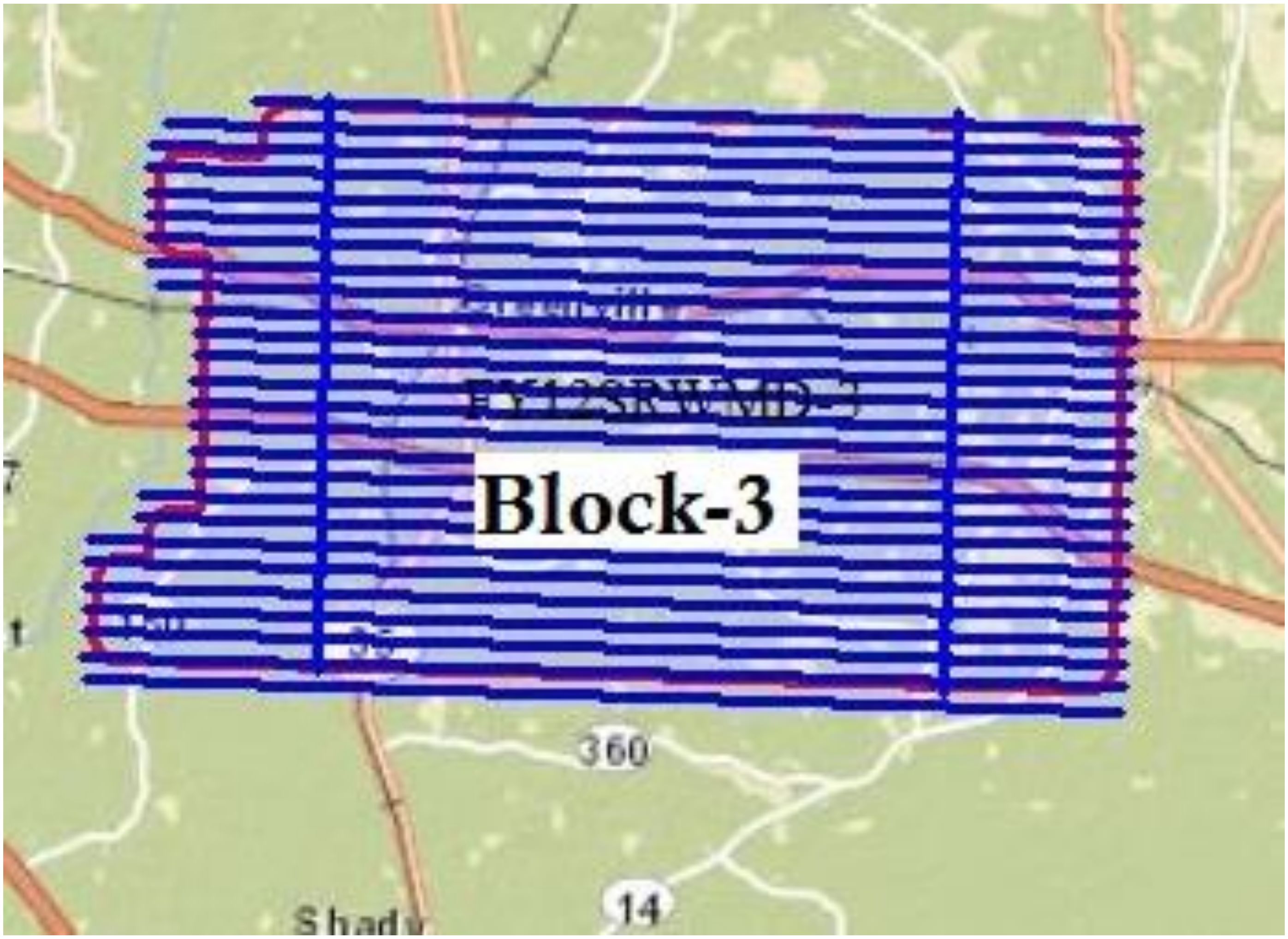
All datasets are available with orthometric elevation; point cloud datasets are also available with ellipsoid heights

- Datum: North American Vertical Datum of 1988 (GEOID09)

3 LiDAR Acquisition

3.1 Survey Area

The Suwannee Management Area 3 survey covers approximately 184 square miles located in north central Florida. The flight plan consisted of 28 survey lines and
2 control lines.



3.2 Acquisition Parameters

Acquisition parameters include the sensor configuration and the flight plan characteristics, and are selected based on a number of project specific criteria. Criteria reviewed include the required accuracies for the final dataset, the land cover types within the project survey area, and the required nominal pulse spacing. Acquisition parameters selected for the Suwannee River water Management Area 3 LiDAR project are summarized below.

Parameter	Value
Flying Height Above Ground Level	5,575 feet
Nominal Sidelap	30%
Nominal Speed Over Ground	140 knots
Field of View	30°
Laser Rate	200 kHz
Scan Rate	68.4 hz
Maximum Cross Track Spacing	0.98 meters
Maximum Along Track Spacing	0.98 meters
Average Spacing	1 meter

3.3 Acquisition Mission

The acquisition mission for the Suwannee Management Area 3 LiDAR survey was coordinated to be acquired in 1 week. Collection began on January 21st 2013 and was completed on January 22nd, 2013, A complete flight log for the acquisition mission may be found in Appendix A.

3.4 Airborne GPS/IMU

Airborne global positioning system (GPS) and inertial measurement unit (IMU) data was collected on the aircraft during the acquisition mission, providing sensor position and orientation information for geo-referencing the LiDAR data. Airborne GPS observations were collected at a frequency of 2Hz, and IMU observations are collected at a frequency of 200Hz.

Aircraft	Sensor	GPS Lever Arm (m)	IMU Lever Arm (m)
C421 – N112MJ	ALS60 – SN6130	x: -0.210, y: -0.060, z: -1.370	x: -0.450, y: -0.159, z: -0.169

In addition, GPS data was collected with ground base stations during the acquisition mission, providing corrections to support differential post-processing of the airborne GPS. One ground base station was setup at an NGS Benchmark (Keyport) as the base of operation. The additional ground base station were selected and place threw the project to ensure complete coverage. Ground GPS observations were collected at a frequency of 2Hz.

4 LiDAR Processing

4.1 Acquisition Post-Processing

Once the acquisition was completed, initial post-processing was performed to generate geo-referenced LiDAR elevation point clouds.

The airborne GPS dataset was differentially corrected using the ground base station GPS datasets collected by DAS in Lecia's IPAS software. IPAS computes the GPS dataset corrections in both forward and reverse chronological sequence, obtaining two solutions for the GPS trajectory. The differences between these two solutions were reviewed to ensure a consistent result, and agree within +/- 3cm. The forward and reverse solutions also show good fit between the two different base stations used in the post-processing.

Differentially corrected airborne GPS data was merged with the airborne IMU dataset in Leica's IPAS software through Kalman filtering techniques. IPAS applies the reference lever arms for the GPS and IMU measurement systems during processing to determine the trajectory (position and orientation) of the LiDAR sensor during the acquisition mission. Estimated lever arm values reported posteriori validate the measurements made during sensor installation in the aircraft.

Raw LiDAR sensor ranging data and the final sensor trajectory from IPAS were processed in Leica's ALSPP software to produce the LiDAR elevation point cloud swaths for each flightline, stored in LAS version 1.2 file format. Quality control of the swath point clouds was performed to validate proper function of the sensor systems, full coverage of the project AOI, and point density consistent with the planned nominal pulse spacing. The LiDAR data collected for the Suwannee Management survey Area3 passed these quality control checks.
Swath point clouds were assigned a unique File Source ID within the LAS file format before further processing. Swath files for the Suwannee Management Area 3 LiDAR project were numbered in chronological order of acquisition.

4.2 Geometric Calibration

Geometric and positional accuracy of the LiDAR swath point clouds is highly dependent on accurate calibration of the various subsystems within the LiDAR sensor system. Sensor calibration parameters fall into two categories, one being those parameters proprietary to the manufacturer's sensor design, and the other being parameters common to most commercial airborne LiDAR sensors, the IMU to laser reference system alignment angles (bore-site), and mirror deformation constants (scaling).

The manufacturer specific calibration parameters are applied in Leica's ALSPP software for the ALS60 sensor system. Terrasolid's Terramatch software was used to calculate the IMU bore-site and mirror scale parameters for the Suwannee Management's Area 3 LiDAR data. Within the TerraMatch software, the Tie-line workflow was used to solve for the parameters. The Tie-line workflow involves automated selection of numerous 'tie-lines', which represent a linear segment fit to the data that should have the same slope, azimuth, position and elevation, within the overlap sections of the survey lines and control lines. The tie- lines provide observations for algorithms within TerraMatch to solve for the bore-site and mirror scale parameters for the lift.

The Tie-line workflow is dependent upon well distributed tie-lines throughout the swath point clouds to effectively solve for bore-site and mirror scale parameters with the automated algorithms. The Suwannee Management survey area did not support this requirement, due to the large water area within the survey and control lines. Manual estimation of the bore-site and mirror scale parameters was performed using the observed tie-lines in overlap areas.

The final step of geometric calibration is to determine elevation (z) offset corrections to be applied to the swath point clouds. Z values calculated during the course of the acquisition mission can vary at the centimeter level as the GPS satellite constellation observed in the survey area changes with satellites moving through their orbits over the course of the mission. Baseline length from the ground base station GPS to the airborne GPS can also impact the z values calculated for the swath point clouds. Z offset corrections are calculated in two steps; a relative step, where individual lines are corrected one to another using the adjusted tie-lines from the bore-site and mirror scale calculation step; and an absolute step, where groups of lines are leveled to project ground control.

For the Suwannee Management Area 3 LiDAR project, the control lines were used to determine relative z offset corrections in areas of discernible ground. The base station operated by DAS in the survey area provided for minimal baseline lengths, resulting in generally good z agreement between the survey lines and control lines.

The final geometrically calibrated swath point clouds were compared to the bare-earth profile survey data. The data fit the profile surveys within the vertical accuracy tolerance specified for the project. Full documentation of the vertical accuracy checks maybe found in section 5.1.

4.3 Point Cloud Classification

Georeference information was applied to the swath point could LAS files. Geometrically calibrated swath point clouds were cut into 4900 foot x 4900 foot State Plane tiles for point cloud classification and derived product creation. It is important to note that US National Grid tiles are non- orthogonal when stored and displayed in a geographic coordinate system. As a result, tiled vector data does not have overlap, but tiled raster data does have overlap to permit seamless display of the data products.

Tiled point cloud data was processed in Terrasolid’s Terrascan software to assign initial classification values. The Terrascan software provides a number of routines to algorithmically detect and assign points to their appropriate class. Points left unclassified by the algorithmic routine remain as Class 1 – Processed, but unclassified. Automated classification routines assigned points to one of the following classes:

- Class 1 – Processed, but unclassified
- Class 2 – Bare-earth ground
- Class 7 – Noise
- Class 9 – Water
- Class 10 – Ignored Ground
- Class 11 – Withheld
- Class 17 – Reserve
- Class 18 – Reserve

Automated classification results were reviewed for each tiled point cloud, and manual edits made where necessary to correct for misclassified points. Points remaining in Class 1 after the automated classification routines were run were left in Class 1. Points falling outside of a 100 meter buffer of the project AOI polygon were excluded from the tiled point clouds.

4.4 Breakline Collection

Manual breakline collection was performed to support the hydro-flattening requirements of the project's DEM deliverables. Breaklines were collected directly from the classified point clouds and from triangulated irregular network (TIN) surface models built from the classified point clouds, in Terrasolids's Terrascan and Terramodeler software. Breakline features were collected as design file elements in Bentley's Microstation software. Breaklines were converted to ESRI 3D shapefile format for the breakline deliverable, and tiled to the project US National Grid index.

The data collected for the Suwannee Management LiDAR Area 3 survey maintained significant point density in the water, marsh, and swamp, limiting the usefulness of point density as guiding factor in breakline placement.

Points classified as Class 2 – Bare-earth ground, falling within a one meter buffer of the collected breaklines, were reassigned to Class 10 – Ignored Ground. These points are excluded from the surface model during DEM generation to preserve the hydro-flattening characteristics of the breaklines.

4.5 DEM Generation

The final classified point clouds and collected breaklines were reviewed for completeness and conformance to the task order scope of work and the NGP version 13 guidelines. Within the Terramodeler software, points in Class 2 – Bare-earth ground and the breaklines were combined to generate TIN elevation models for each tile, from which the bare-earth DEM tiles were interpolated and exported as 32 bit float Arc Grid.

5 Quality Control

5.1 Point Clouds

Accuracy and completeness of the LiDAR point clouds directly impacts the quality of all other derived LiDAR derived products. Ensuring a quality LiDAR dataset begins with proper mission planning and execution. Ground GPS base stations are located such that GPS baselines between the ground and airborne receivers do not exceed 30km. For the Suwannee Management LiDAR project, two base stations were run to meet this requirement, one at the field operations airport and one within the survey area. Static alignment is performed both before take-off and after landing to allow for GPS integer ambiguity resolution. Sensor operators carefully monitor the LiDAR unit and its various subsystems during the acquisition mission to ensure proper function. Airborne GPS positional dilution of precision (PDOP) estimates are monitored to ensure they remain less than 3.The optical system is monitored to ensure there are no ranging errors encountered during the flight lines.

During acquisition post-processing estimates of the trajectory data accuracy are reviewed to ensure they will support the required accuracies of the point cloud data. The trajectory accuracy is a function of the differentially corrected GPS data and the IMU data.

The raw swath point clouds generated from ALSPP are reviewed as another check for proper sensor function. The point clouds are reviewed for full coverage of the AOI, required point density and nominal pulse spacing, clustering, proper intensity values, full swath coverage within the planned field of view, and planned survey line overlap.

Geometric calibration quality control validates that the positional accuracy requirements of the project are met, and includes relative accuracy assessments for intra-swath (within) and inter-swath (between) accuracy, along with absolute accuracy assessments against project ground control.

Relative vertical accuracy assessments are normally made using the tie-lines generated in the Terramatch software, as these lines provide positional observations throughout the extent of individual swaths, and between neighboring swaths.

Horizontal accuracy assessments of LiDAR data require the presence of vertical targets such as buildings within in the survey area. Field check points are surveyed at the corners of the building roofs, and the surveyed locations compared to the estimated corner locations in the LiDAR point cloud. The Suwannee Management survey area did not present any accessible buildings for use as vertical targets. From the manufacturer's specifications, the estimated horizontal accuracy at one sigma, based on flying height for the project, is between 10cm and 20cm.

Absolute vertical accuracy assessments for the point cloud data are made against ground check point data. For the Suwannee Management Area 3 survey, ground check point data consisted of the ground GPS base station, and real-time kinematic (RTK) GPS techniques.

Check point locations were collected at 1 – second intervals during the RTK survey. Points collected during the static pre-initialization and post-initialization were removed from the assessment so as not to bias the assessment.

Local TIN models of the elevation points are built around each ground check points. The tin model elevation is sampled at the horizontal position of the ground check point. The TIN model elevation and ground check point survey elevation values were used to calculate the fundamental vertical accuracy (FVA) of the swath point clouds as described in NDEP Elevation Guidelines Version 1. The FVA of the TIN tested RMSEz 0.239 feet and 0.472 feet at the 95% confidence level in open terrain. FVA of the DEM tested at an RMSEz of 0.298 feet and 0.587 feet at the 95% confidence level in open terrain. The full calculations for all check points can be found in Appendix B.

FVA of TIN

$RMSE_Z$ =	0.239	feet
NSSDA=	0.472	feet

FVA of DEM

$RMSE_Z$ =	0.298	feet
NSSDA=	0.587	feet

The tiled point cloud products were reviewed for full coverage of the AOI and proper classification. As part of the QC process, TINs are built in the Terramodeler software for each tile using the ground class and the hydro-flattening breaklines. The TINs are reviewed for non-ground features, and edited where necessary to remove any remaining non-ground features. Points were also reviewed for absolute elevation, and points falling below the selected orthometric elevation for water were removed from the ground class.

5.2 Breaklines

The final breaklines in ESRI 3D shapefile format were reviewed for topological consistency and correct elevation. Breaklines features are continuous and do not have overlaps or dangles.

5.3 Digital Elevation Models

Digital elevation models (DEMs) were reviewed for conformance with the SOW and the NGP version 1 guidelines. DEM files were loaded in the Global Mapper software and inspected visually for edge matching between tiles, void areas within the project AOI, and proper coding of the NODATA values. DEM file naming was verified for consistency with the US National Grid tile index.

Appendix A. Flight Logs

DAS
Digital Aerial Solutions

ALS60 LiDAR Flight Log

Project	Suwannee 2013	ALS60	N6130_090724	Sensor Operator/s
			-	Meagan McCall
Date/Julian:	1/21/2013	Mem Drive MM60	Int. Time: TAR AIRSPD (KNTS)	Base PID:
Hobbs End	664.4 Perry	3-600093051	140	40JA
				Pilot/s: Weazel
Hobbs ST	659.8	LIFT A	TAR ALT AGL (ft): 5,575	Flight Plan(s): Block 3
Flight Time	4.6		Base Height: 1.500	Aircraft: 421C 112MJ; Airport Idnt: 40J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
						-	-	-	130				Static Alignment
		178	130121_165418	16:54	17:00	5,603	270	131	128	16	1.2	0.7	CLEAR
		179	130121_170517	17:05	17:12	5,627	90	139	127	16	1.2	0.7	CLEAR
		180	130121_171725	17:17	17:24	5,619	270	129	125	16	1.3	0.7	CLEAR
		181	130121_172839	17:28	17:35	5,628	90	143	123	16	1.2	0.7	CLEAR
		182	130121_174007	17:40	17:47	5,600	270	129	121	16	1.3	0.7	CLEAR
		183	130121_175104	17:51	17:58	5,623	90	142	119	16	1.3	0.6	CLEAR
		184	130121_180447	18:04	18:12	5,583	270	134	118	17	1.2	0.6	CLEAR
		185	130121_181612	18:16	18:22	5,639	90	145	116	19	1.2	0.6	CLEAR
		186	130121_182624	18:26	18:33	5,616	270	132	114	19	1.1	0.6	CLEAR
		187	130121_183630	18:36	18:43	5,637	90	144	113	19	1.1	0.6	CLEAR
		188	130121_184636	18:46	18:53	5,634	270	135	111	18	1.1	0.6	CLEAR
		189	130121_185632	18:56	19:03	5,650	90	141	109	16	1.2	0.6	CLEAR
		190	130121_190629	19:06	19:13	5,611	270	134	107	18	1.2	0.6	CLEAR
		191	130121_191635	19:16	19:23	5,632	90	148	106	17	1.3	0.7	CLEAR
		192	130121_192608	19:26	19:33	5,609	270	138	104	18	1.2	0.6	CLEAR
		193	130121_193602	19:36	19:42	5,632	90	142	102	17	1.3	0.6	CLEAR
		194	130121_194550	19:45	19:53	5,615	270	136	101	18	1.3	0.6	CLEAR
		195	130121_195607	19:56	20:03	5,646	90	141	99	19	1.2	0.6	CLEAR
		196	130121_200622	20:06	20:14	5,629	270	135	97	20	1.0	0.6	CLEAR
		197	130121_201709	20:17	20:24	5,647	90	137	95	19	1.1	0.6	CLEAR
		198	130121_202735	20:27	20:35	5,627	270	134	93	19	1.0	0.6	CLEAR
		199	130121_203839	20:38	20:45	5,639	90	143	91	19	1.0	0.6	CLEAR
		204	130121_205235	20:52	20:57	5,644	0	134	90	19	1.0	0.6	X STRIP
		204	130121_210047	21:00	21:05	5635	180	140	89	18	1.1	0.6	X STRIP

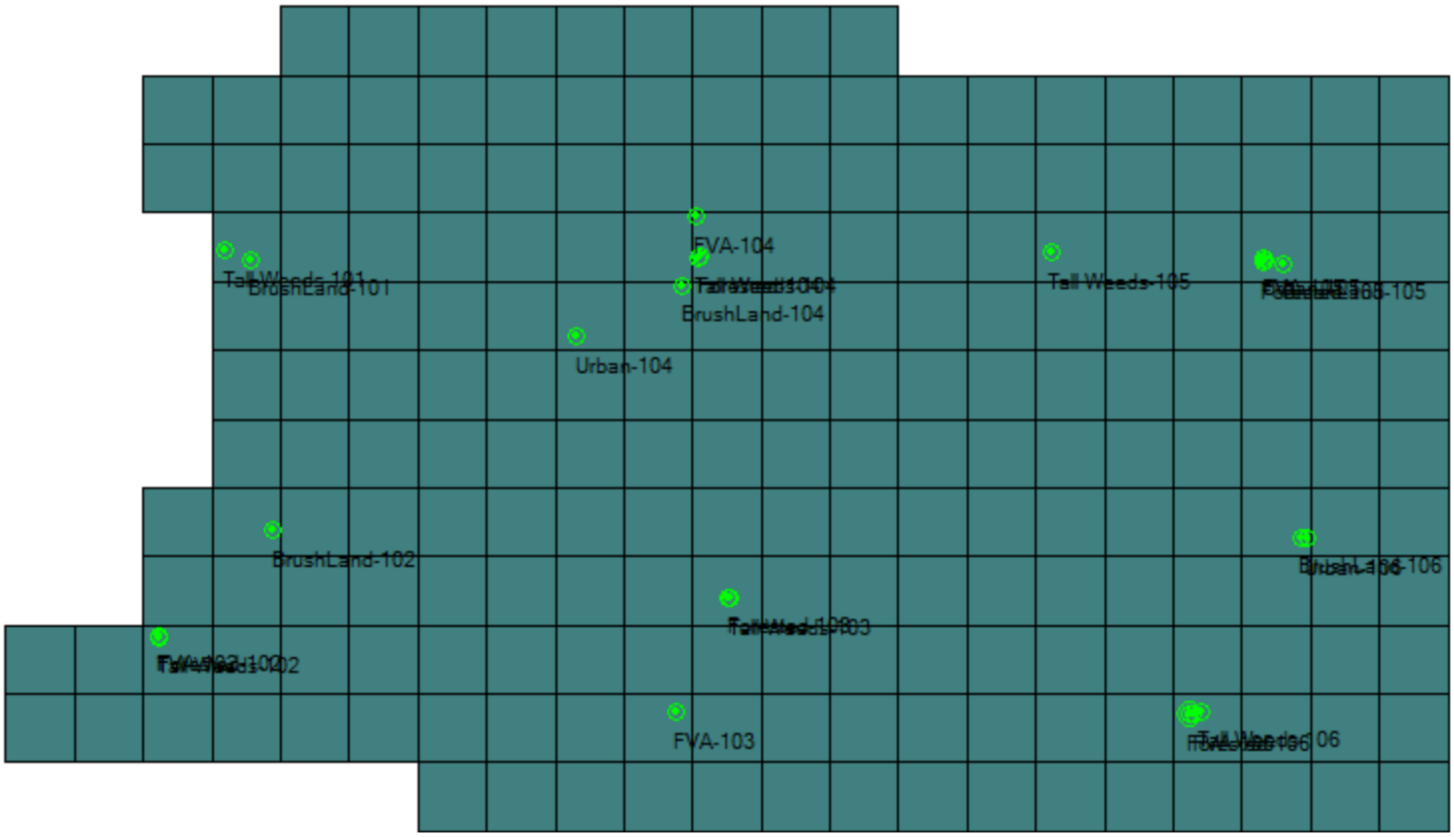
ALS60 LiDAR Flight Log

Project	Suwannee 2013	ALS60	N6130_090724			Sensor Operator/s	
				-		Meagan McCall	
Date/Julian:	1/22/2013 Perry	Mem Drive MM60	Int. Time:	TAR AIRSPD (KNTS)	Base PID:	Pilot/s	
Hobbs End	665.8	3-600093051		140	40JA	MWAZ	
Hobbs ST	664.4	LIFT A		TAR ALT AGL (ft):	Flight Plan(s):	Base Height:	Aircraft	Airport Idnt:
Flight Time	1.4			5,575	Block 3	1.500	421C 112MJ	40J

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Memory	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
						-	-	-	89				Static Alignment
		199	130122_142735	14:27	14:34	5,646	90	142	87	16	1.1	0.7	CLEAR
		200	130122_143825	14:38	14:45	5,619	270	137	85	16	1.2	0.6	CLEAR
		201	130122_144856	14:48	14:56	5,644	90	138	83	15	1.4	0.7	CLEAR
		202	130122_145939	14:59	15:07	5,635	270	140	82	15	1.4	0.7	CLEAR
		203	130122_151224	15:12	15:16	5,674	90	138	81	15	1.4	0.7	CLEAR
		204	130122_152221	15:22	15:24	5,670	0	136	80	15	1.3	0.7	X STRIP
		204	130122_152746	15:27	15:30	5,664	180	140	79	15	1.3	0.7	X STRIP

Appendix B. Vertical Accuracy Calculations

Tiled-Data Area



LiDAR Accuracy Assessment Summary

LC Type	# of Points	FVA	SVA	CVA
LAS				
ALL	24			0.501
FVA	5	0.472		
Urban	3		0.269	
Tallweeds	6		0.692	
Brushland	5		0.383	
Forested	5		0.380	
Total	24			
DEM				
ALL	24			0.574
FVA	5	0.587		
Urban	3		0.262	
Tallweeds	6		0.675	
Brushland	5		0.387	
Forested	5		0.364	
Total	24			

Units: Feet

Coordinates and Offsets of Analyzed Locations

		ID				
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
1)	☑	FVA-102					
			239319.534	3367271.011	24.724	24.539	24.567
					-0.185	-0.157	FVA
2)	☑	FVA-103					
			250631.994	3365608.869	28.853	28.791	28.851
					-0.062	-0.002	FVA
3)	☑	FVA-104					
			251057.124	3376411.507	31.295	31.314	31.296
					0.019	0.001	FVA
4)	☑	FVA-105					
			263474.967	3375505.639	48.843	48.84	48.84
					-0.003	-0.003	FVA
5)	☑	FVA-106					
			261949.185	3365556.972	53.652	53.594	53.605
					-0.058	-0.047	FVA
6)	☑	Urban-104					
			248456.576	3373788.795	43.369	43.295	43.3
					-0.074	-0.069	Urban
7)	☑	Urban-105					
			263500.583	3375468.553	48.227	48.146	48.143
					-0.081	-0.084	Urban

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
8)	☑	Urban-106					
			264408.198	3369397.22	57.715	57.647	57.653
					-0.068	-0.062	Urban
9)	☑	Tall Weeds-101					
			240781.081	3375678.163	25.138	25.197	25.165
					0.059	0.027	Tallweeds
10)	☑	Tall Weeds-102					
			239352.666	3367234.809	23.437	23.418	23.427
					-0.019	-0.01	Tallweeds
11)	☑	Tall Weeds-103					
			251823.476	3368086.898	28.503	28.512	28.487
					0.009	-0.016	Tallweeds
12)	☑	Tall Weeds-104					
			251099.476	3375531.059	27.738	27.993	28.01
					0.255	0.272	Tallweeds
13)	☑	Tall Weeds-105					
			258834.423	3375626.464	31.173	31.18	31.178
					0.007	0.005	Tallweeds
14)	☑	Tall Weeds-106					
			262105.234	3365624.109	52.233	52.258	52.233
					0.025	0	Tallweeds

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
15)	☑	BrushLand-101					
			241331.908	3375487.905	25.889	25.804	25.768
					-0.085	-0.121	Brushland
16)	☑	BrushLand-102					
			241828.702	3369561.621	27.221	27.123	27.137
					-0.098	-0.084	Brushland
17)	☑	BrushLand-104					
			250781.994	3374909.689	33.343	33.463	33.429
					0.12	0.086	Brushland
18)	☑	BrushLand-105					
			263912.28	3375386.873	35.372	35.26	35.271
					-0.112	-0.101	Brushland
19)	☑	BrushLand-106					
			264273.822	3369411.323	56.785	56.751	56.763
					-0.034	-0.022	Brushland
20)	☑	Forested-102					
			239349.948	3367271.262	22.943	23.066	23.07
					0.123	0.127	Forested
21)	☑	Forested-103					
			251774.902	3368099.853	28.86	28.796	28.789
					-0.064	-0.071	Forested

Coordinates and Offsets of Analyzed Locations (Continued)

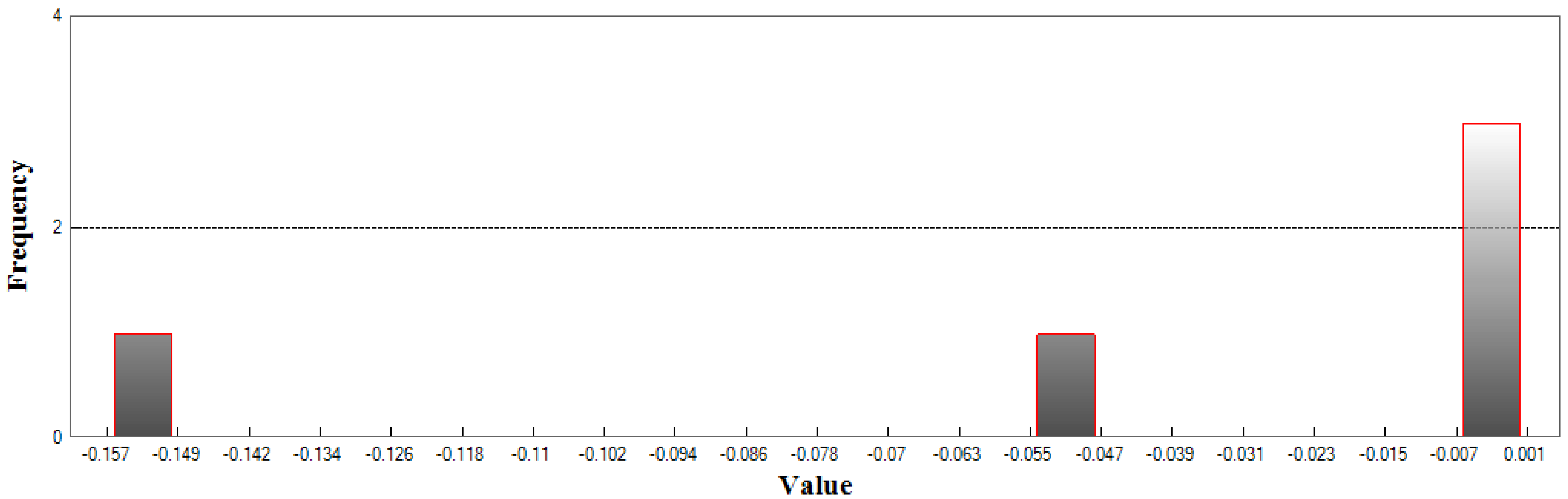
		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
22)	☑	Forested-104					
			251141.269	3375535.368	29.424	29.47	29.459
					0.046	0.035	Forested
23)	☑	Forested-105					
			263457.648	3375407.618	47.482	47.454	47.452
					-0.028	-0.03	Forested
24)	☑	Forested-106					
			261831.698	3365546.63	50.384	50.35	50.354
					-0.034	-0.03	Forested

LAS

Fundamental Vertical Accuracy

LandCover Type: FVA
Minimum DZ: -0.515
Maximum DZ: 0.003
Mean DZ: -0.137
Mean Magnitude DZ: 0.672
Number Observations: 5
Standard Deviation DZ: 0.223
RMSE Z: 0.239
95% Confidence Level Z: 0.472
Units: Feet

Histogram



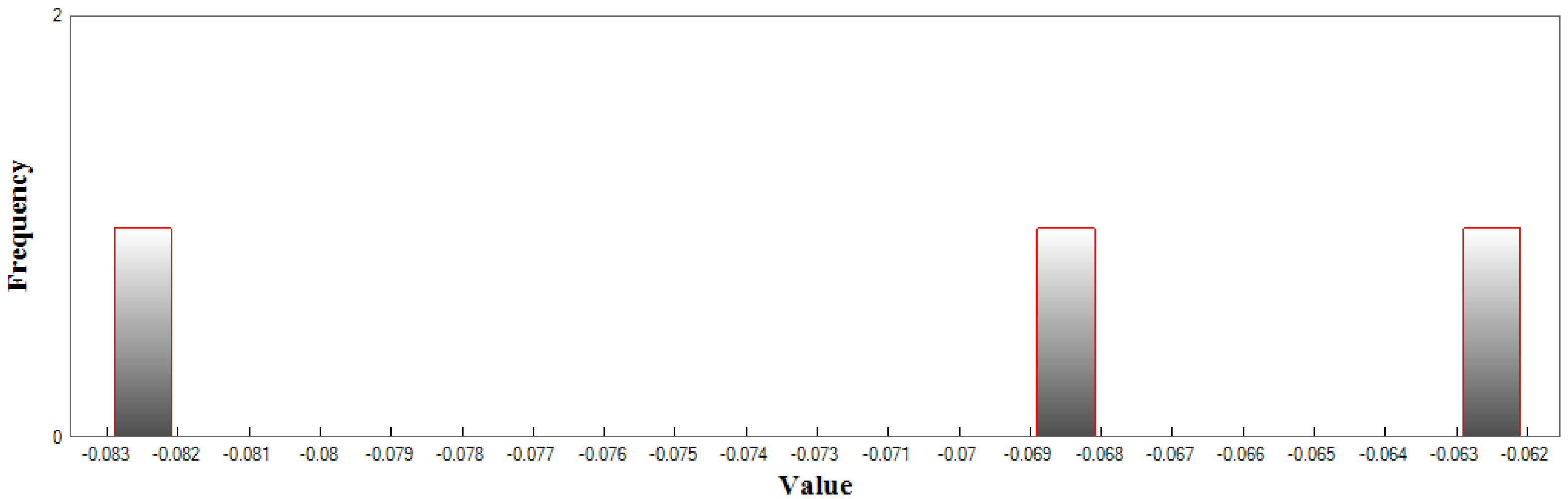
Min: -0.157
Max: 0.001
Number Of Bins: 20
Bin Interval: 0.008

LAS (Continued)

Supplemental Vertical Accuracy

LandCover Type: Urban
Minimum DZ: -0.275
Maximum DZ: -0.203
Mean DZ: -0.236
Mean Magnitude DZ: 0.879
Number Observations: 3
Standard Deviation DZ: 0.036
RMSE Z: 0.236
95th Percentile: 0.269
Units: Feet

Histogram



Min: -0.084
Max: -0.062
Number Of Bins: 20
Bin Interval: 0.001

LAS (Continued)

Supplemental Vertical Accuracy
LandCover Type: Tallweeds

Minimum DZ: -0.052

Maximum DZ: 0.892

Mean DZ: 0.150

Mean Magnitude DZ: 0.770

Number Observations: 6

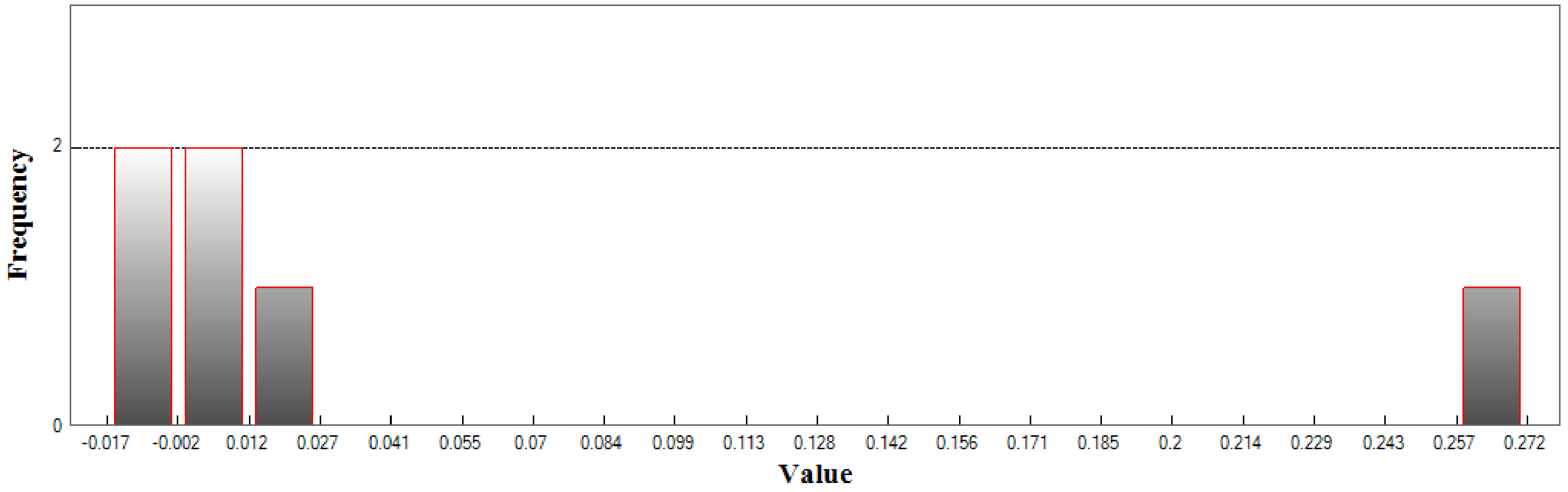
Standard Deviation DZ: 0.367

RMSE Z: 0.367

95th Percentile: 0.692

Units: Feet

Histogram



Min: -0.016

Max: 0.272

Number Of Bins: 20

Bin Interval: 0.014

LAS (Continued)

Supplemental Vertical Accuracy
LandCover Type: Brushland

Minimum DZ: -0.396

Maximum DZ: 0.282

Mean DZ: -0.157

Mean Magnitude DZ: 0.944

Number Observations: 5

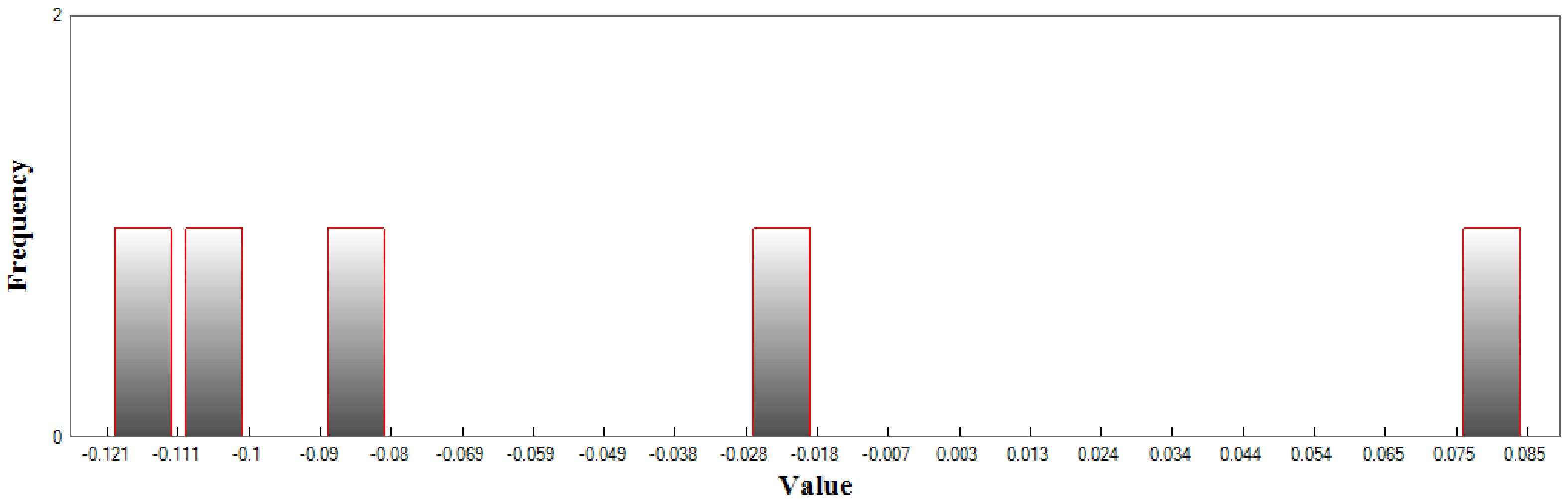
Standard Deviation DZ: 0.275

RMSE Z: 0.291

95th Percentile: 0.383

Units: Feet

Histogram



Min: -0.121

Max: 0.086

Number Of Bins: 20

Bin Interval: 0.01

LAS (Continued)

Supplemental Vertical Accuracy
LandCover Type: Forested

Minimum DZ: -0.232

Maximum DZ: 0.416

Mean DZ: 0.006

Mean Magnitude DZ: 0.793

Number Observations: 5

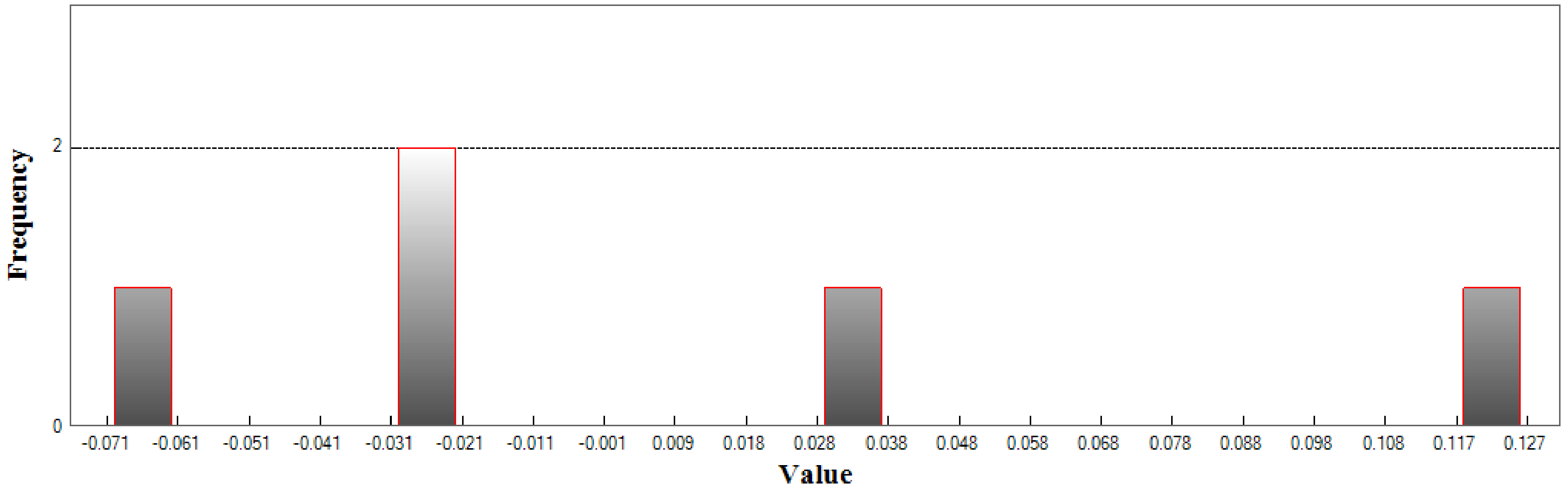
Standard Deviation DZ: 0.252

RMSE Z: 0.229

95th Percentile: 0.380

Units: Feet

Histogram



Min: -0.071

Max: 0.127

Number Of Bins: 20

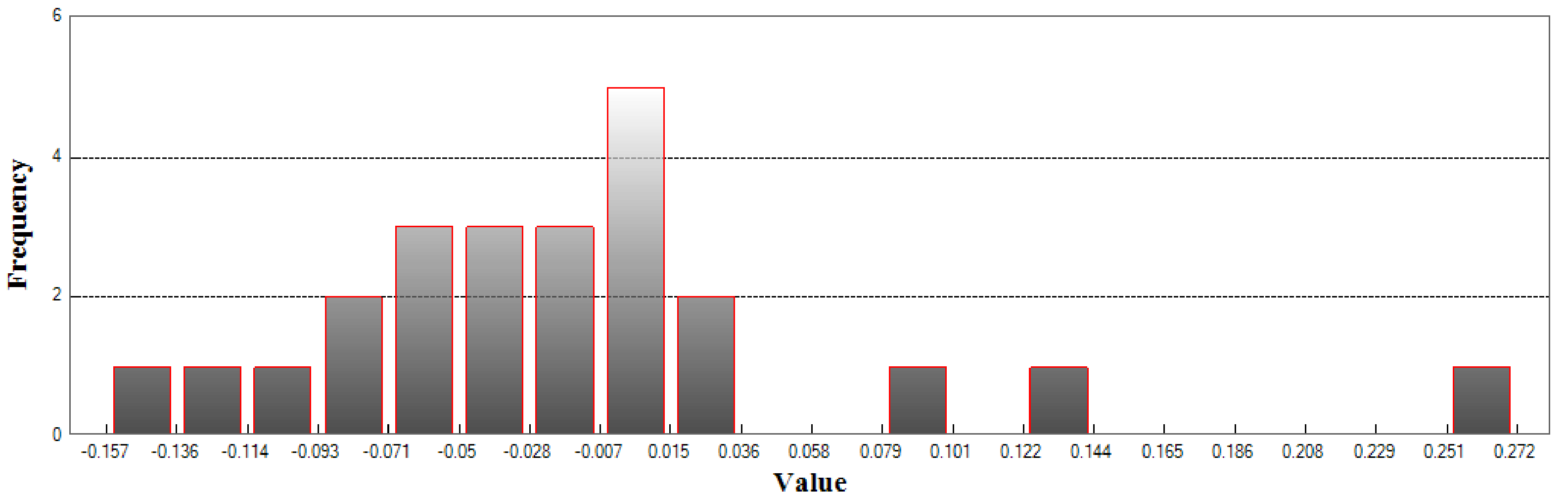
Bin Interval: 0.01

LAS (Continued)

Consolidated Vertical Accuracy

LandCover Type: ALL
Minimum DZ: -0.515
Maximum DZ: 0.892
Mean DZ: -0.049
Mean Magnitude DZ: 0.810
Number Observations: 24
Standard Deviation DZ: 0.288
RMSE Z: 0.285
95th Percentile: 0.501
Units: Feet

Histogram



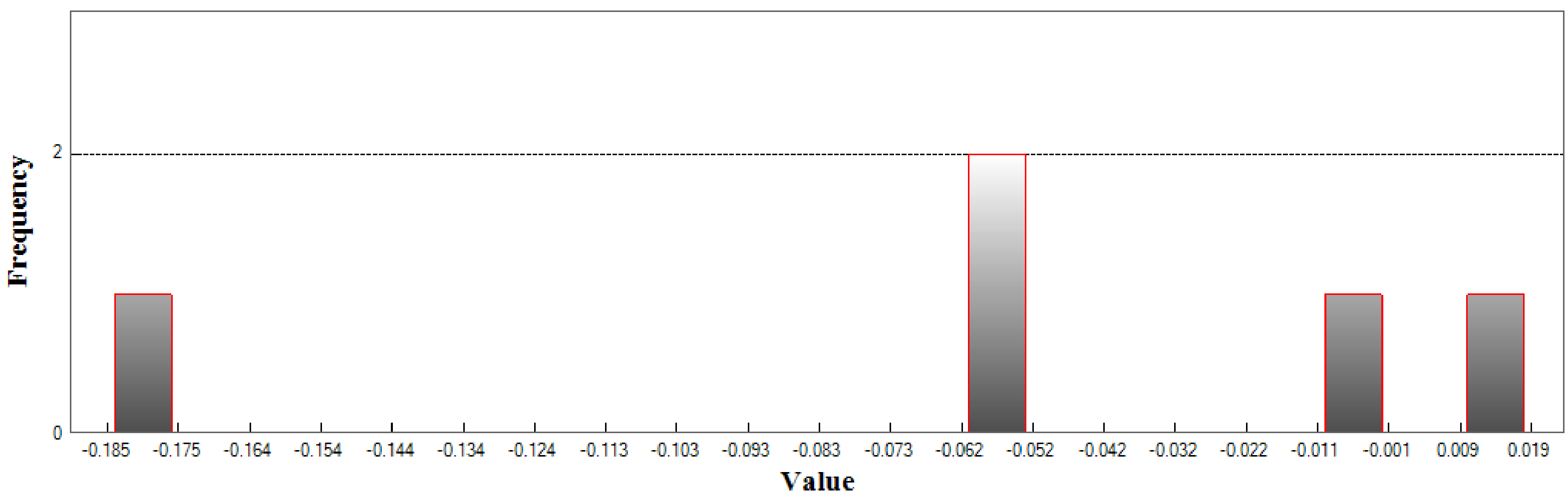
Min: -0.157
Max: 0.272
Number Of Bins: 20
Bin Interval: 0.021

DEM

Fundamental Vertical Accuracy

LandCover Type: FVA
Minimum DZ: -0.606
Maximum DZ: 0.062
Mean DZ: -0.623
Mean Magnitude DZ: 0.839
Number Observations: 5
Standard Deviation DZ: 0.259
RMSE Z: 0.298
95% Confidence Level Z: 0.587
Units: Feet

Histogram



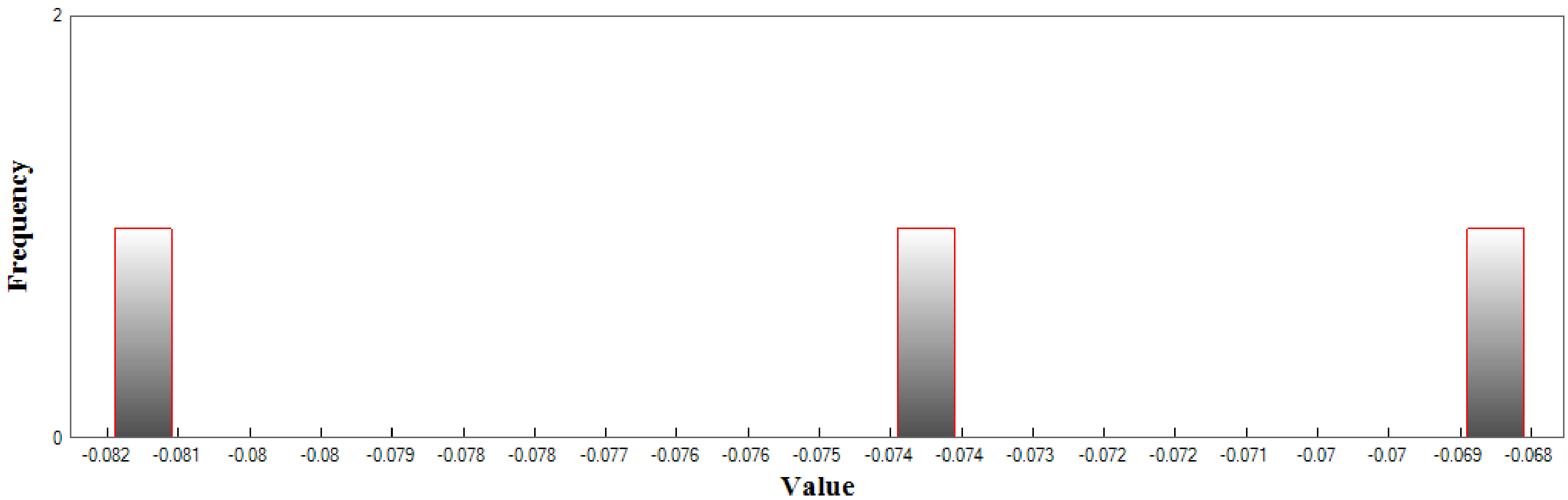
Min: -0.185
Max: 0.019
Number Of Bins: 20
Bin Interval: 0.01

DEM (Continued)

Supplemental Vertical Accuracy

LandCover Type: Urban
Minimum DZ: -0.265
Maximum DZ: -0.223
Mean DZ: -0.242
Mean Magnitude DZ: 0.895
Number Observations: 3
Standard Deviation DZ: 0.022
RMSE Z: 0.242
95th Percentile: 0.262
Units: Feet

Histogram



Min: -0.081
Max: -0.068
Number Of Bins: 20
Bin Interval: 0.001

DEM (Continued)

Supplemental Vertical Accuracy
LandCover Type: Tallweeds

Minimum DZ: -0.062

Maximum DZ: 0.836

Mean DZ: 0.183

Mean Magnitude DZ: 0.820

Number Observations: 6

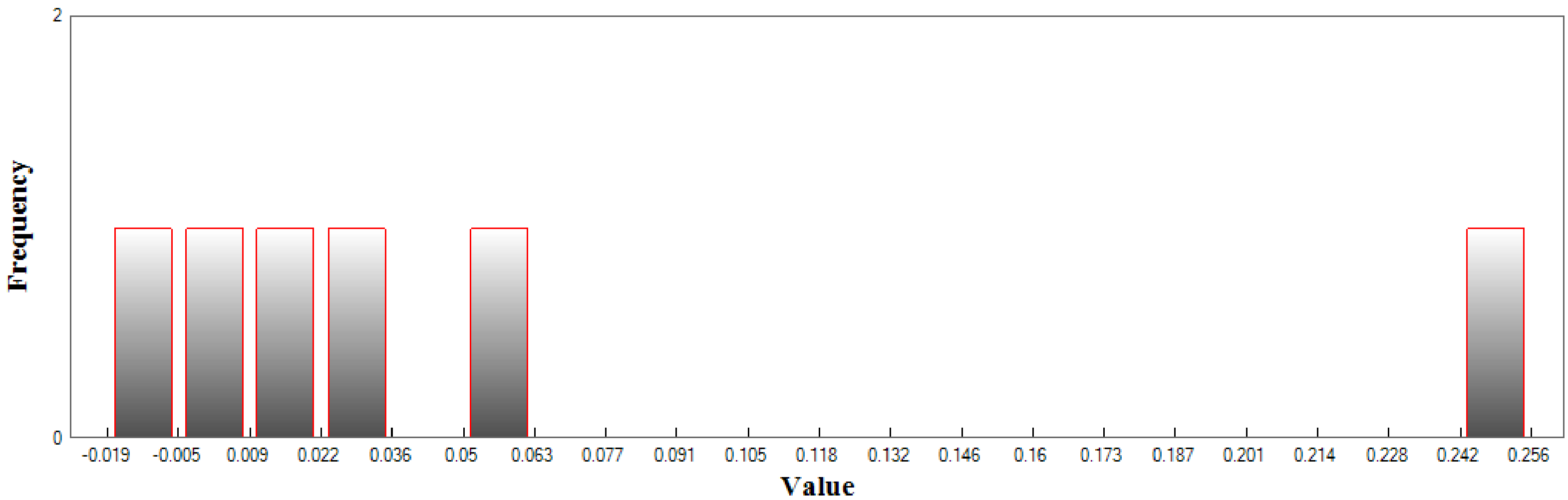
Standard Deviation DZ: 0.331

RMSE Z: 0.354

95th Percentile: 0.675

Units: Feet

Histogram



Min: -0.019

Max: 0.255

Number Of Bins: 20

Bin Interval: 0.014

DEM (Continued)

Supplemental Vertical Accuracy
LandCover Type: Brushland

Minimum DZ: -0.367

Maximum DZ: 0.393

Mean DZ: -0.137

Mean Magnitude DZ: 0.980

Number Observations: 5

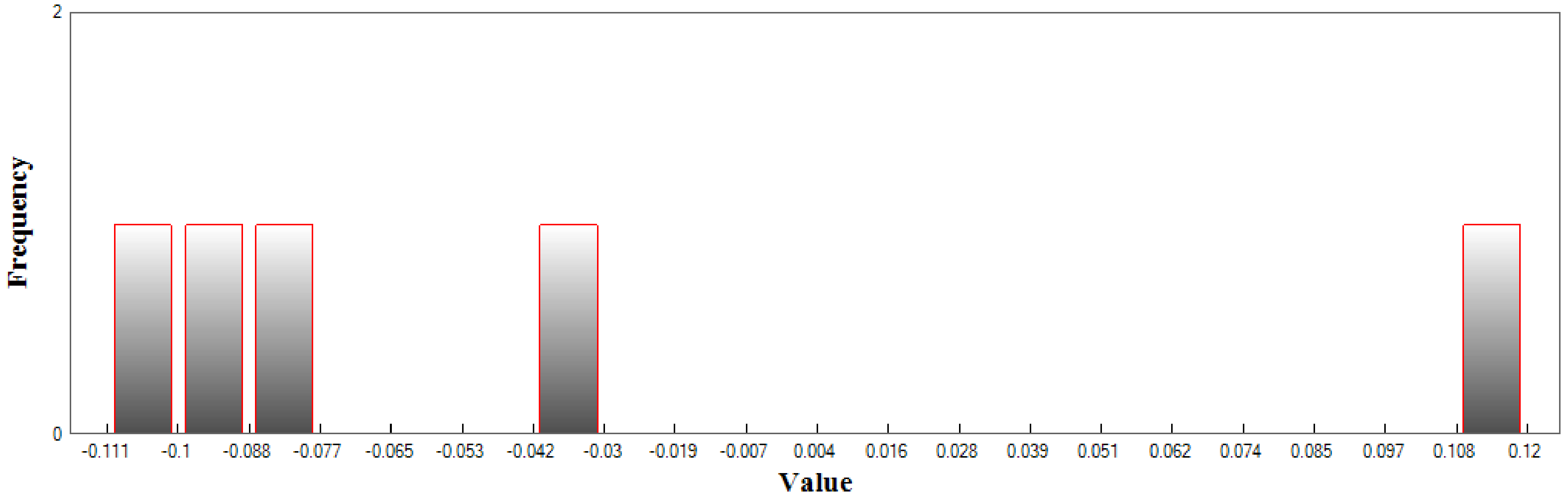
Standard Deviation DZ: 0.311

RMSE Z: 0.311

95th Percentile: 0.387

Units: Feet

Histogram



Min: -0.112

Max: 0.12

Number Of Bins: 20

Bin Interval: 0.012

DEM (Continued)

Supplemental Vertical Accuracy
LandCover Type: Forested

Minimum DZ: -0.209

Maximum DZ: 0.403

Mean DZ: 0.029

Mean Magnitude DZ: 0.797

Number Observations: 5

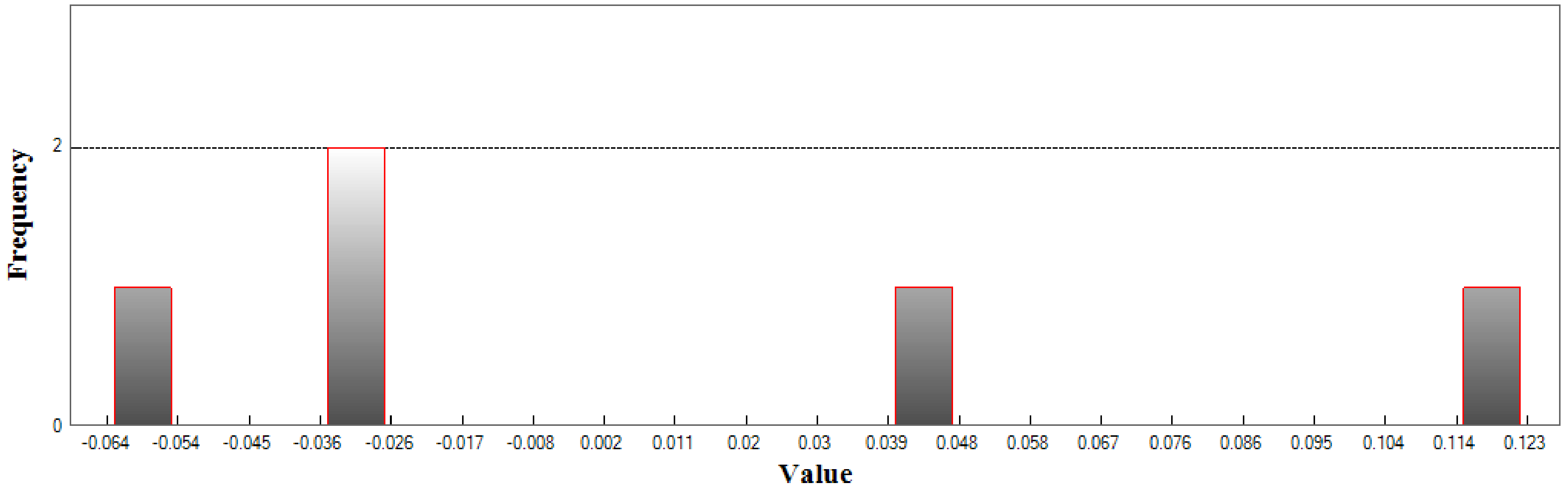
Standard Deviation DZ: 0.249

RMSE Z: 0.223

95th Percentile: 0.364

Units: Feet

Histogram



Min: -0.064

Max: 0.123

Number Of Bins: 20

Bin Interval: 0.009

DEM (Continued)

Consolidated Vertical Accuracy

LandCover Type: ALL

Minimum DZ: -0.606

Maximum DZ: 0.836

Mean DZ: -0.045

Mean Magnitude DZ: 0.862

Number Observations: 24

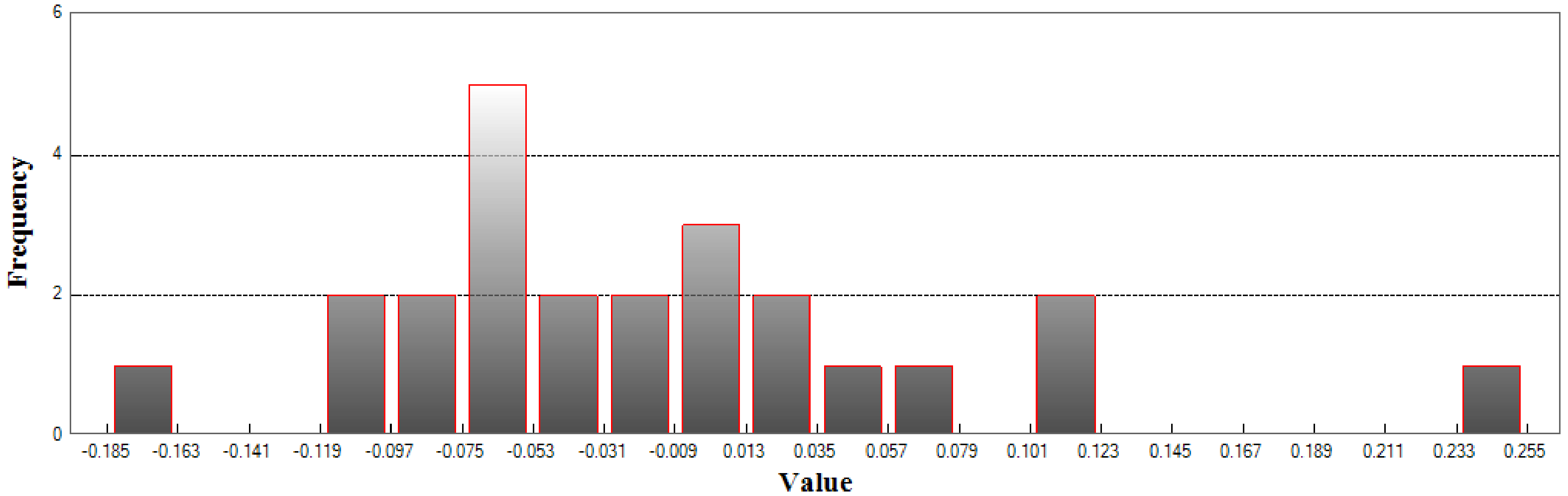
Standard Deviation DZ: 0.298

RMSE Z: 0.295

95th Percentile: 0.574

Units: Feet

Histogram



Min: -0.185

Max: 0.255

Number Of Bins: 20